Engineering positioning test in Flanders: a powerful predictor for study success?

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Conference Topic: The Attractiveness of Engineering; Education al Research Methods

INTRODUCTION

A new positioning test for the Bachelor of Engineering Science was broadly and uniformly implemented in Flanders in the summer of 2013 [1]. The non-mandatory test measures the ability of future engineering students to solve engineering problems and compares a student's mathematical skills with the required prior knowledge. This paper is the first one to analyse the predictive power of the positioning test. Specifically, this paper studies the impact of the positioning test on the enrolment and the impact on the study trajectory of the studies (trial exams and January results) at the KU Leuven Bachelor in Engineering Science and the Bachelor in Engineering Science - Architecture.

1 POSITIONING TEST FOR BACHELOR ENGINEERING SCIENCE FLANDERS

1.1 Context

Historically a multi-topic entrance exam for the study of Engineering Science has existed in Belgium for more than 100 years, stimulating, as a preparation, a high level of mathematics education in high schools and resulting in an international high reputation of the Flemish mathematics secondary school education (see PISA assessments in 2003 [2]). But, despite academic opposition, the entrance exam at Flemish universities was abolished in 2004 following a decision of the Flemish Government. The bachelor of Engineering Science program was consequently adapted to accommodate more students and to introduce more basic mathematics in the first year in order to maintain the same level of

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expectations for the other courses. Despite these efforts the success rate dropped from 70% with the entrance exam to less than 50%.
Almost a decade later, the evolutions in secondary schools, student populations, and industry expectations have triggered a renewed effort to deploy new tests taking into account this new context. This effort is supported by the results of the SOHO report [3], which expressed a number of concerns and actions concerning mathematics education in high schools. One of the concerns was the need for a positioning test before the start of university studies in fields that rely strongly on mathematics.
The result of this effort is a positioning test called “ijkingstoets”. The non-obligatory and non-mandatory test measures the ability of future engineering students to solve engineering problems and compares a student’s mathematical skills with the required prior knowledge. The goal of the test is threefold: firstly, to encourage students that succeed; secondly, to stimulate students that are less successful to better prepare by entering a remediation trajectory; thirdly, to advise students that badly fail against entering the engineering studies.
While it was not a primary objective of the test to accurately predict the chances of success or the study progress in the engineering studies [1], the validity of the positioning test will be supported if the positioning test proofs to have predictive power. This paper presents the first analysis of the predictive power of the positioning test.

1.2 History of the Positioning test

After a pilot version in 2012, the “ijkingstoets” positioning test for engineering students in Flanders was fully implemented for the first time in 2013. This test is organized twice: in July and September. Students are free to enrol in both. As described before [1], the test consists of 35 multiple choice questions to meet the requirements of a high throughput and multi-location (three different universities, four locations) test with the possibility of quick feedback. For each question five possible answers are mentioned and negative marking [4,5] was applied as a scoring rule, with a score of +1 for marking the correct answer, -1/4 for marking a wrong answer and 0 for unanswered (blank) questions. The final score are recalculated to a score on 20. The questions are designed based on the concepts taught in the high school curriculum (6 hours of mathematics in the final years) relevant for the courses of the first year of the bachelor of Engineering Science and covered several topics: mathematical reasoning, mathematical concepts, mathematical skills, spatial visualization ability, and mathematics in an applied context. Special focus lies on questions that combine different parts of mathematics and questions that cannot be solved with ‘off-the-shelf’ recipes. Students can use a list of formulas but no calculators.

2 LITERATURE

In the transition from secondary school to university three phases are distinguished, the recruitment phase and activities, examination and application phase, and the registration phase. This paper is considering the examination phase and the impact of the examination phase on the application phase. Since the procedures of transition from secondary to university are strongly depending on the context, we restrict ourselves to a comparison with other European universities.
The ATTRACT project [6] has studied the three transition phases in five European countries: Belgium, Finland, Ireland, Italy, Portugal, and Sweden. The different countries all use different admission requirements both on the level of general admission requirements (school certificate exams, ongoing performance at second-level, entrance exams, …) and additional admission requirements for engineering courses (maths, physics, chemistry, biology). In Europe, the system of Italy, and the Politechnico di Torino (PoliTo) in particular is most comparable to Flanders. Italian universities, just like the Flemish ones, have to admit any student with a secondary school diploma, so no subject-specific entry requirements are imposed. To counteract the high attrition rates in the first year, PoliTo has created an aptitude test in the core subjects of mathematics, logic, and comprehension for new students [7]. Different from the Flanders’ positioning test, the aptitude test is mandatory for all incoming students. But identically to the Flanders’ positioning test, the aptitude test does not influence admission and is meant to inform the student. Nevertheless, the test has been proven to be highly effective in predicting the student achievement during the first year: students who score highly on the test gain a significantly higher number credits during the first year, while those with low test scores obtain very few credits [6].
Other studies have proven the importance of mathematics and results obtained in secondary education. Related to study success: the prior achievement in higher-level mathematics is the most significant positive factor for predicting performance in first-year university exams (Trinity College

Dublin, Ireland). Related to academic achievement: the results obtained in secondary education have the most significant impact on academic achievement (Instituto Superior Técnico, Portugal) [6]. Remarkably, a Finnish study conducted at the University of Oulu concludes that the prior performance in upper secondary school does not correlate with performance in university. This again stresses the importance of the local context.

3 STUDY OF 2013 POSITIONING TEST

3.1 Results of the 2013 positioning test

612 students participated in the first positioning test organised in **July 2013** across three universities in Flanders. The overall success rate was 56% and the average score was 10.03/20 (SD 3.47) with a normally distributed test score as shown in *Fig. 1*. 107 of the 267 failed students took the second positioning test in **September 2013** of which 49,5% succeeded. 137 new students participated as well in September, of which 84 succeeded (61%).
The rest of the study focuses on the students who participated in the position test at KU Leuven (July or September) and/or enrolled for the Bachelor of Engineering Science or the Bachelor of Engineering Science - Architecture for the academic year 2013-2014. Fig. 2 nicely presents the student flow from the positioning tests up to enrolment at KU Leuven. As can be seen from the figure, 223 (55%) of the 407 participants succeeded in the July positioning test; 93 (51%) of the failed students took the second positioning test of which 51% succeeded. 79 new students participated in September, of which 46 (58%) succeeded.

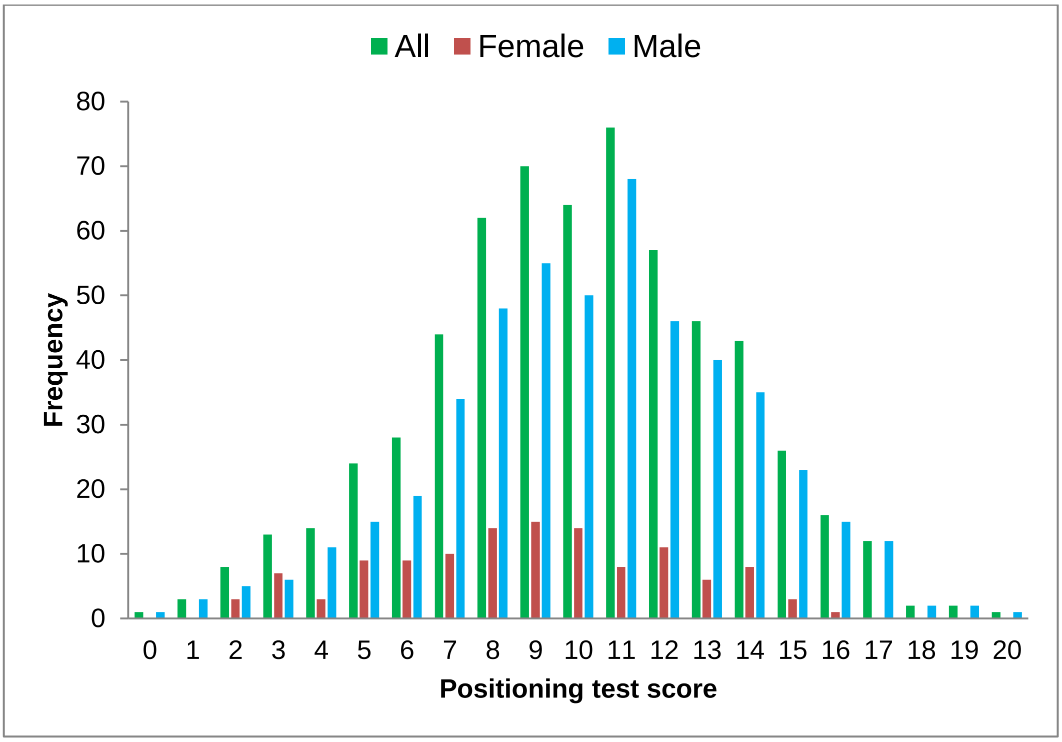

Fig. 1. Positioning test scores of July 2013

3.2 Enrolment at KU Leuven

As shown by Fig. 2 and Table 1 only a limited number of students who failed the positioning test decided not to enrol in the Bachelor of Engineering Science. This can be partially explained by the fact that it was the first time that the positioning test was fully implemented. Especially the discouraging effect of the September is low (the time between the positioning test and the start of the academic year is only a week). This is supported by a field study by the KU Leuven in 2012 in Flanders, which showed that by the month of June at least 90% of the candidates has made a stable choice of study program.

Table 1. Number of participants in the 2013 positioning test that did not enrol in the Bachelor of Engineering Science at KU Leuven.

	Number participants			**Number of participants that did not enrol**			**% participants that did not enrol**		
best score positioning test	**all**	**male**	**female**	**all**	**male**	**female**	**all**	**male**	**female**
<5	25	15	10	10	7	3	40,0%	46,7%	30,0%
5 -> 9	145	100	45	36	27	9	24,8%	27,0%	20,0%
10 -> 13	219	178	41	19	14	5	8,7%	7,9%	12,2%
>13	98	87	11	3	3	0	3,1%	3,4%	0,0%
TOTAL	**487**	**380**	**107**	**68**	**51**	**17**	**14,0%**	**13,4%**	**15.9%**

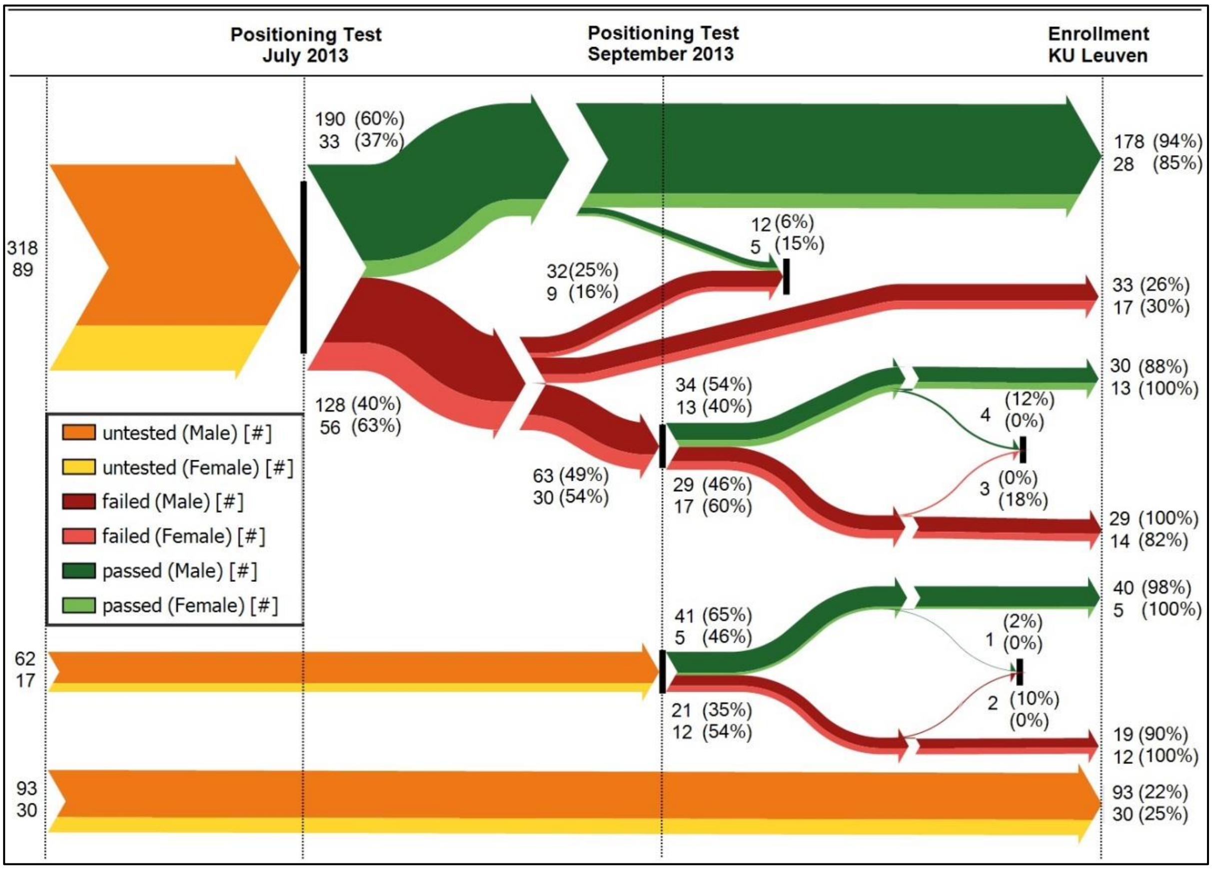

Fig. 2. Student flow diagram across the positioning tests of July and September 2013 up to enrolment at KU Leuven. Students that participated in the positioning test at KU Leuven and/or enrolled at KU Leuven are included. The values alongside the arrows indicate the number of students (top-bottom:male-female); the percentages indicate the fraction within a specific gender (e.g. 60% of the male students passed the July positioning test).

3.3 Math Course and trial exams

3.3.1 *Mathematics for problem solving*

At KU Leuven, students that pass the positioning test get an exemption for the course “Mathematics for problem solving” (further on referred to as the ‘Math course’). The course is therefore only attended by students that failed or did not participate in the positioning test. The goal of this course, which takes place in the first weeks of the academic year, is to improve the mathematical skills of the students to better match the requirements for the other BSc courses. The examination of this course occurred in the same week as the intermediate tests (see below). 49% of students that failed the positioning test completed the math course successfully. The math course success rate (51%) was not significantly better for the students that hadn't participated in the positioning tests (see lower left part of *Fig. 4*).

3.3.2 Trial exams

In November students could participate in a trial exam for two courses of the first semester. The goal of the test is to make students familiar with the examination style and test their current knowledge. The intermediate test results are taken into account for 25% in the final grade of the student only if it improves the final grade. As an example, *Fig. 3 compares* the 'calculus' trial exam results with the positioning test results. In this group, 42% of students who failed the positioning test can improve their basic mathematical skills during the start of the academic year and pass the Math course. But practically all of them subsequently fail in the trial exams. Studying new courses while catching up on basic mathematics proves to be very difficult for students who failed the positioning test. On the contrary, the trial exam success-rate of the untested students that passed the Math course successfully is comparable to the success-rate of students that passed the positioning test. Many of the untested students have enough prior knowledge and succeed in combining the Math course with the trial exams.

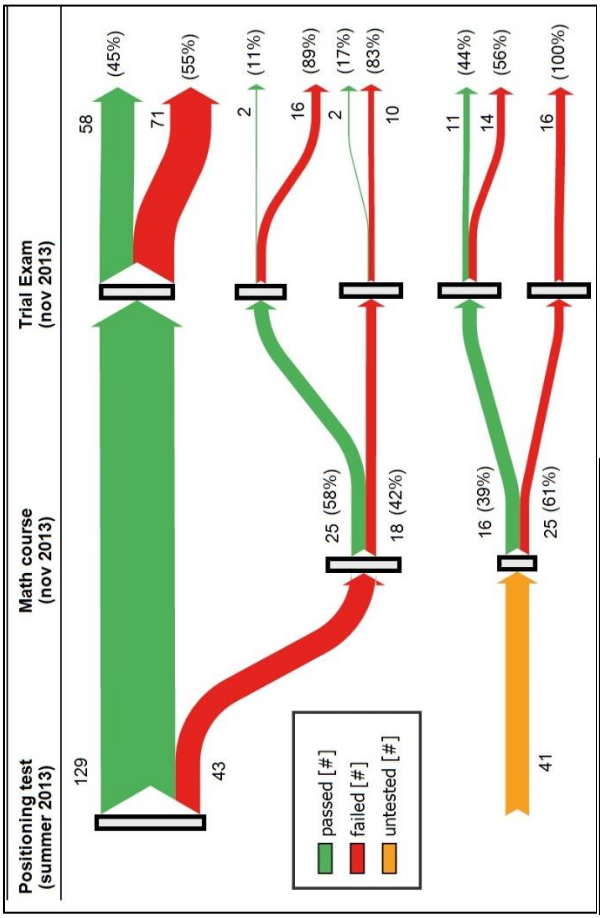

Fig. 3. Student flow diagram across positioning test, math course and trial exam for the students participating in the calculus trial exam. The values alongside the arrows indicate the number of students; the percentages indicate the fraction within a branch.

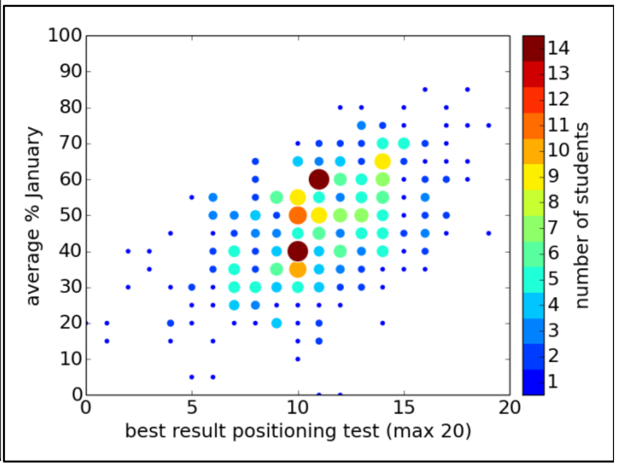

Fig. 4. Comparison of the best positioning test result with the weighted average score in the January exams. Marker colour and radius indicate number of students.

3.4 January examination period

In January 2014, the first year students participated in examinations for six courses for a total of 30 credits in the Bachelor of Engineering Science and 23 credits in the Bachelor of Engineering Science - Architecture. Two overall indicators for the January exams are calculated: the cumulative study efficiency (CSE, % of obtained credits from total semester credits) and the weighed overall percentage (WOP, course results weighed by the number of course credits).

To further analyse the study results, we defined three categories of students based on their January examination results. These are defined according to the experience of the tutors, which is confirmed by data from previous academic years (data not published). The categories are defined in *Table 2*. Group A includes the students that have a good chance of succeeding (obtaining all credits) in the first academic year after the June examination period (no re-examinations in September), group B has a good chance of succeeding in the first year after the September examination period (re-examination for some courses), while group C has little chance of succeeding in the first academic year.

Table 2. Student group definition based on January examination results.

Group	interpretation	Number of courses passed (>9/20)	Number of courses failed but tolerable (8 or 9/20)	Number of courses failed (<8/20)
A	good chance of obtaining all credits in the first academic year after the June examination period	Minimum 5	Maximum 1	0
B	good chance of obtaining all credits in the first academic year after the September examination period	Rest group		
C	little chance of obtaining all credits in the first academic year			Minimum 2 or CSE<50%

Fig. 5 shows the student flow related to the positioning test results using these categories. It is clear that the lower the score on the positioning test, the more difficult it is for students to have good prospects for their first academic year. This figure shows that the main goal of the positioning test is obtained: the test can detect students with little chance of succeeding in the bachelor before they enter the study program. Students with a positioning test score equal or lower than 10/20 have a low chance of obtaining good results in January (77% badly fails). This results shows that the prior knowledge deficiency can't be remediated in only one semester. However, passing the positioning test is no guarantee for study success. Other features such as motivation, study effort, study method, and stress-handling, which are not tested during the positioning test, are important as well.

While this was not the goal of the positioning test, the positioning test result shows a small linear correlation with the CSE and the WOP (R^2=0.21 and R^2=0.29, respectively) as can be seen for the WP in *Fig.4.* The positioning test results are thus a good, but not a perfect indicator for the January examination results.

4 CONCLUSION

The new positioning test for the Bachelor of Engineering Science was broadly and uniformly implemented in Flanders for the first time in the summer of 2013. The positioning test measures the ability of future engineering students to solve engineering problems and compares a student's mathematical skills with the required prior knowledge. This paper is the first one to analyse the predictive power of the positioning test. Specifically, this paper studied the impact of the positioning test on the enrolment and the impact on the study trajectory of the studies (trial exams and January results) at the KU Leuven Bachelor in Engineering Science and the Bachelor in Engineering Science - Architecture. This study results in three main conclusions

1. **The positioning test has achieved its main goal of identifying students with low chance**

of study success: the test can detect students who have little chance of succeeding in the bachelor before they enter the study. Concretely, students with a 2013 positioning test score equal or lower than 10/20 have a low chance of obtaining good results in January (77% badly fails). While passing the positioning test increases the chance on study success it does not guarantee study success. Other features such as motivation, study effort, study method, and stress-handling are important.

2. **Despite its predictive power the positioning test does not succeed in advising students that badly fail the test against enrollment:** only 40% of the students that obtain a 2013 positioning test score lower than 5/20 do not enroll in the Bachelor of Engineering Science. Especially the September positioning test fails in discouraging students who badly failed.
3. **Studying new courses while catching up on basic mathematics thus proves to be very difficult for students who failed the positioning test:** students that failed the positioning test are obliged to improve their basic math skills in an obligatory course. These students however perform badly during the trial exams.

The obtained results concerning the predictive power of the positioning test support the positioning test. These results are already used to convince future students to subscribe for the positioning test and will be used to inform students about the “significance” of the obtained positioning test result. As such, we hope that the positioning test will better succeed in discouraging students that badly fail the positioning test. Finally, we hope that this will have an impact on student retention and drop-out, which is the subject of future research.

In the future, we will further study the predictive power of the test by looking at the first year achievement of the students, the number of years needed to obtain a bachelor degree, etc.

Since the paper shows that it is hard to study new courses while catching up on basic mathematics, we will further investigate more appropriate remediation for prior knowledge deficiencies such as more elaborate summer courses, part-time study programs supplemented with remediation courses, etc.

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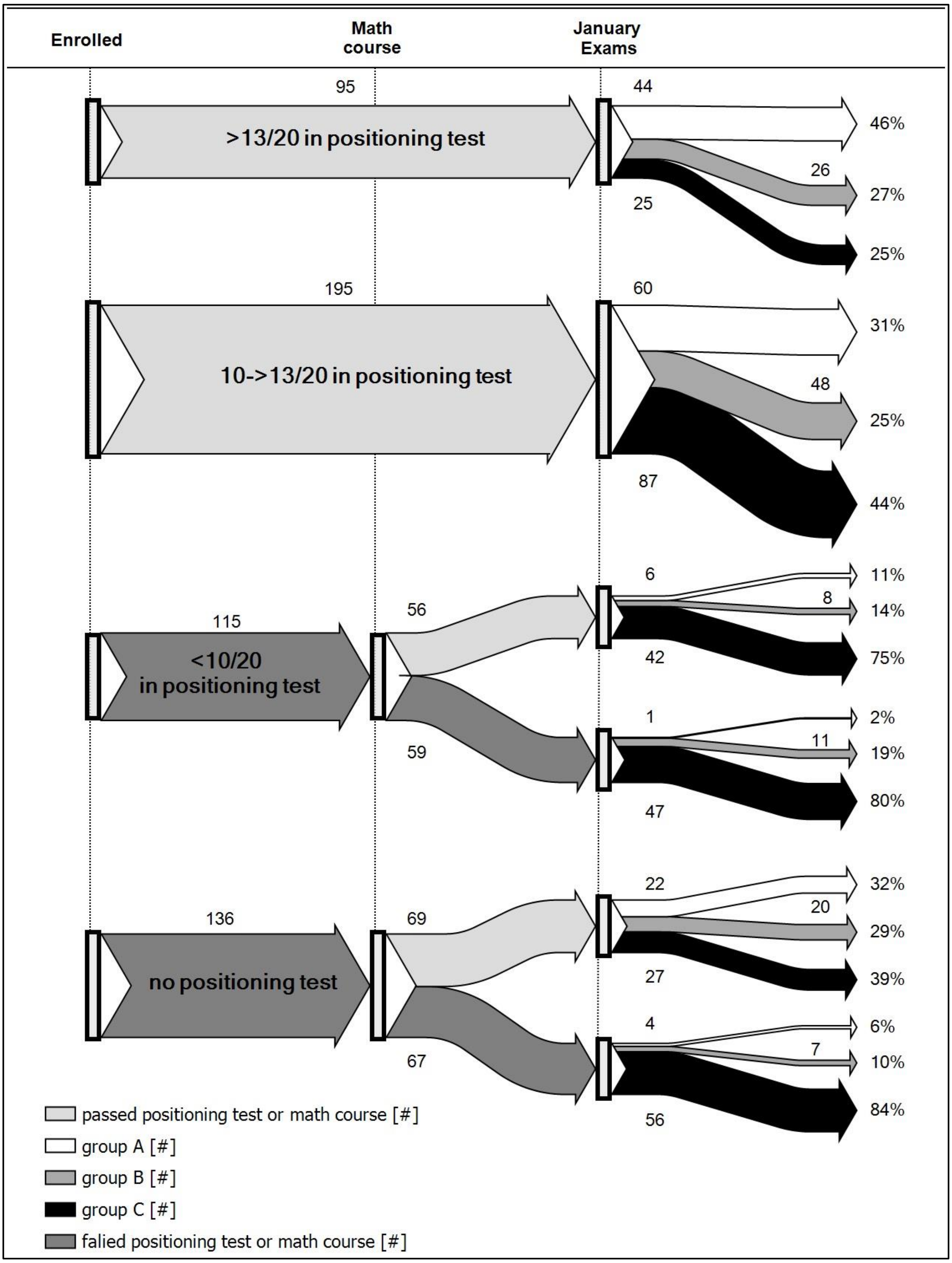

Fig. 5. Student flow diagram showing enrolment, math course, and January examination period in relation to positioning test results. January examination results were categorised in three groups (A,B,C) as explained in Table 2. The values alongside the arrows indicate the number of students; the percentages indicate the fraction within a specific branch (e.g. 46% of the students with >13/20 on the positioning test belong to group A after the January exams).